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M&S Data Engineering Technical Framework (M&S DE-TF)

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0.1.0	DEC 96	Jack Sheehan, et al	initial draft
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1. Introduction

1.1 Purpose

This paper specifies the Modeling and Simulation Data Engineering Technical Framework (M&S DE-TF). Within the Modeling and Simulation Common Technical Framework [1], the M&S DE-TF is:

- the formal vehicle for promulgating and enforcing data standards, and
- a template for using data standards to create, manage, and deliver data .

In particular, the DE-TF (Figure 1) provides data:

- recognition through common semantics and syntax,
- realization through data systems architecture,
- repeatability through a closed-loop engineering process
- reuse through standard data products, and
- standards through M&S functional data administration .

1.2. Applicability

The M&S Data Engineering Technical Framework version 0.2 applies to all DMSO sponsored organizations, products, and activities within the scope of the DoD Directive 5000.59 Modeling and Simulation Master Plan [1].

1.3. Organization

This specification of the M&S Data Engineering Technical Framework is organized as follows. Section 1 introduces the DE-TF. Section 2 provides an overview of the fundamental concepts and components of the framework. Section 3 provide a detailed expositions of the DE-TF products and processes. Lengthy expositions or extended examples are provides as enclosures. References, figures, and tables are collected in to Sections 4, 5, and 6, respectively. Section 7 provides a DE-TF specifications compendium. Where appropriate, technical derivations or detailed trade-studies are referenced as external documents. Specific data standards which provide formal Interface Design Descriptions (IDD) are referenced as external annexes to this document.

1.4. Objectives

The traditional DoD M&S product development and delivery paradigm enforces a rigorous, top-down procedure where:

- requirements are derived from specific operational needs,
- designs are derived from requirements, and
- custom components are created to implement the design.

While producing individually excellent products, this exclusively top-down procedure leads to stove-piped M&S solutions with these undesirable side-effects:

- limited interoperability and re-use between independently conceived products,
- reduced credibility of results when the stove-pipe does not include key communities, and
- response to changing requirements can be costly in time, resources, and quality.

A fundamental objective of DoD Directive 5000.59 is to address these undesirable side-effects by developing the infrastructure required for composable solutions. Composable solutions employ the principle of design inversion where:

- requirements are derived from specific operational needs,
- families of standard plug-and-play components are retained in a repository, and
- specific designs are created to meet the requirements using existing components from the repository.

In particular, the DoD M&S Master Plan [1] has directed the development of an M&S Common Technical Framework (Objective 1), authoritative representations of the environment, units and systems, and human behavior (Objectives 2-4), and infrastructure (Objective 5)required to enable composable solutions.

The Defense Modeling and Simulation Office (DMSO) is leading the effort to develop the required M&S Common Technical Framework (M&S CTF). The M&S CTF has three principal components:

- High Level Architecture (HLA)
- Conceptual Models of the Mission Space (CMMS), and
- Data Standards

as directed in DoD Directive 5000.59. Within the M&S Common Technical Framework and the associated authoritative representation objectives, the Data Engineering Technical Framework is

- the formal vehicle for promulgating and enforcing data standards, and
- a template for using data standards to create, manage, deliver, and employ data .

M&S activities will employ the DE-TF to provide composable data solutions which are:

- derived from authoritative sources,
- described using common semantics and syntax
- interchanged using standard formats,
- subject to rigorous quality checks,
- released to authorized consumers and,
- protected from unauthorized access or modification.

In particular, the data standards incorporated into the DE-TF (Figure 1) will provide

- Recognition of structure and content through common semantics and syntax, including:
  - standard naming conventions in a common lexicon,
  - entity-based and action-based data element dictionaries,
  - common taxonomies within identified application clusters,
  - layered architecture which separates implementation and problem domain semantics,
  - integration with existing standards from other (non-M&S) functional areas,
  - capture, matching, and mapping procedures and utilities,
- Realization of instance values within a data systems architecture, including
  - the Modeling and Simulation Resource Repository (MSRR) [1, 2] for consistent physical access and network connectivity,

- families of interfaces (low-level formats, intermediate-level API, high-level GUI, etc.), and
- hardware/software platform standards and constraints.

- Repeatability through data development processes which provide
  - a standard Data Production Sequence, and
  - a closed-loop Data Engineering Process.
- Reuse through data products, specifically:
  - development and designation of Authoritative Data Sources,
  - information exchange using Data Interchange Formats,
  - specification and employment of Data Quality (DQ) practices and
  - specification and enforcement of Data Security (DS) practices.
- Standards through DoD M&S Functional Data Administration (M&S FDAd).

DMSO is developing the DE-TF in conjunction with the JSIMS and JWARS M&S development programs, the Defense Information Systems Agency (DISA) with their associated Component and Functional Data Administrators, and the OSD PA&E Joint Data System. DMSO anticipates that a number of other Service and Component data programs will also make significant contributions to the DE-TF including: the Defense Intelligence Agency MIDB and MEPED, the Naval Warfare Tactical Database (NWTDB), and the Air Force MASTR database.

1.5. Specifications

DE-TF specifications are captioned:

- Minimum Requirement: mandatory specification considered necessary (but not necessarily sufficient) for data interoperability and re-use.
- Preferred Practice: best practices specification considered sufficient for data interoperability and re-use.
- Technology Extension: optional specification which in not considered mandatory for data interoperability and re-use but which is considered indicative of the technology adoption trend.

2. Fundamental Concepts

The DE-TF specification provided here will employ reserved words, first to define basic terms and concepts and then construct more general and complex terms and concepts from the basics:

RESERVED WORD

A specific term or concept which is defined and used to specify the Data Engineering Technical Framework. These terms will be typed in bold small caps.

Following the DoD M&S Master Plan [1], the definitions provided in the Glossary of M&S Terms [3], and the DoD Data Dictionary System (DDDS) [4] are included here as **RESERVED WORDS** by reference. Changes or extensions to these external definitions in this Data Engineering Technical Framework are italicized in the body of the definition.

2.1 Basic Definitions

This section develops the inter-related concepts of: data, model, information, representation, simulation, and resource in the context of modeling and simulation requirements. These terms are then employed to define fundamental data engineering concepts.

DATA

Specification of facts, *parameters*, *values*, concepts, or instructions in a formalized manner suitable for communications, interpretation, or processing by humans or by automatic means. This definition of **DATA** is a compatible modification[1] of the definitions in [3-4].

"Messages which resolve ambiguity are information. All other messages are noise." [5]. Therefore:

INFORMATION

DATA in context related to a specific purpose [6].

MODEL

A physical, mathematical, or otherwise logical *specification* of a system, entity, phenomenon, or process. This definition of **MODEL** is a compatible modification of the definitions in [3].

REPRESENTATION

The combination of a **MODEL**, process, or algorithm and the associated **DATA**, parameters, or values. Traditional implementations sharply separate algorithms and values. Contemporary object-oriented implementations joins **MODEL** and **DATA** as an object.

SIMULATION

The implementation of a **REPRESENTATION** over time. This definition is a compatible modification of the definition in [3]

RESOURCE

The entities and expendable which may be used by a process. Resources include **MODELS**, **DATA**, **REPRESENTATIONS**, **SIMULATIONS**, facilities, equipment, systems, software, source code, manpower, computer time, calendar time, funding, etc.

DATA is a critical enabling factor in the composable solutions strategy both as an end in itself and as a means to an end. As an example, consider the HLA Federation Development and Execution Process (FEDEP) depicted in Figure 2. The traditional focus of M&S data standards has been the start-exercise

[1] Replaced "representation" in [4-5] with "specification" to avoid circular definition of **REPRESENTATION**.

scenario instance **DATA** shown in the PRODUCTS block of Figure 2. This is **DATA** as an end in itself. Note that the every arrow on the diagram represents **DATA** interchange. Moreover, over one-half of the blocks on the diagram constitute **RESOURCES** which can converted to/from **DATA** for archive and interchange. Even within the TEST and EXECUTION blocks, the composable solutions strategy distributes **SIMULATION** functionality among the federates using HLA-compliant **DATA** interchange. This is **DATA** as a means to an end. The Data Engineering Technical Framework provides the development process, interoperability standards, and integration procedures required for **DATA** within the composable solutions strategy.

2.2 Representation

The cornerstone of the M&S Data Engineering Technical Framework is this: composable **DATA** solutions are feasible precisely when the associated **REPRESENTATION** is explicit. This is the essence of recognition and the jump off point for realization, extension to repeatability, and eventual reuse. In most circumstances, the choice of representation is a matter of focus. Two important components of this choice are

- the real world focus of the military activities of interest (the problem domain) and
- the synthetic world focus of the simulation application (the implementation domain).

2.2.1 Real World Focus

ABSTRACTION

A mental facility that permits humans to view real world problems with varying degrees of detail depending on the current context of the problem [7]. **ABSTRACTION** is the real world equivalent of the synthetic world **REPRESENTATION** used in **SIMULATION**.

Real world military activities have a focus. While all physical and cognitive details of the real entities and their actual behaviors are present with perfect fidelity, not all details are important or are readily discernible in the focus of the real military operation. For example, consider an F/A-18 allocated to a deep penetration air interdiction mission. In the actual military operations, the details which are include or excluded, the granularity and aggregation of information provided to the real warfighter is very different if that warfighter is

- a general officer in the Unified Command,
- the wing commander in the JFACC air operations center,
- the flight leader in the strike package, or
- the pilot of the F/A-18.

That is, the real world executes real operations by introducing distinct **ABSTRACTIONS** which correspond exactly to the real world decomposition of tasks and allocation of **RESOURCES**. Note this introduction of **ABSTRACTION** is part to the problems space -- not the implementation domain.

This use of **ABSTRACTION** is an intrinsically human activity to reduce the full complexity of the real world to manageable proportions by filtering out unnecessary details [13]. Entities, actions, characteristics, and behaviors near the real world focus are **ABSTRACTED** to the real world actors with

- fine-grained decomposition's,
- extensive detail, and
- higher fidelity.

Entities and actions distant from the real world focus are **ABSTRACTED** with

- coarse-grained decomposition's,
- limited detail, and
- lower fidelity.

The objective of these **ABSTRACTIONS** employed in real activities is to provide **DATA** in context, i.e. **INFORMATION,** to support decisions by rejecting noise. In real world or problem domain, the **DATA** is almost always explicitly provided as **INFORMATION**; whereas, the underlying **MODEL** which completes the **ABSTRACTION** usually is implicit. Under the M&S Common Technical Framework, this understanding of the real world is captured and maintained as Conceptual Models of the Mission Space (CMMS) [8].

Minimum Requirement:

> **DATA** created, registered, maintained and released under the M&S Data Engineering Technical Framework shall be traceable to an appropriate **REPRESENTATION** of the corresponding problem domain **ABSTRACTION** registered in CMMS.

2.2.2 Simulation Focus

Just as real operations have a focus, every simulation has a focus. The simulation focus is derived from the real world focus and the simulation objectives as follows:

- Obtain **REPRESENTATIONS** of the real world focus of the entities, actions, tasks, and interactions of interest from CMMS.
- Extend the scope and context of the real world focus to include notional entities/actions, hypothetical situations, and to-be conditions -- again in the form of CMMS **REPRESENTATIONS**.

The simulation objectives are then imposed as constraints on the extended real world focus to complete the simulation focus. These constraints imposed by the simulations are often called the Conceptual Model of the User Space (CMUS) [9]. Typical constraints on the simulation focus include:

- the range of anticipated Essential Elements of Analysis (EEA's) or Measures of Effectiveness (MOE's) in analysis applications,
- the training audience and readiness objectives (e.g. the WarSim Task Requirements Analysis Process or TRAP),
- real-time, faster than real-time, or as fast as possible computational requirements, or perhaps
- the anticipated hardware/software platforms with associate processing limits.

Just as in the real world focus, synthetic entities, actions, characteristics, and behaviors near the simulation focus are **REPRESENTED** with

- fine-grained decomposition's,

- extensive detail, and
- higher fidelity.

And synthetic entities and actions distant from the simulation focus are **REPRESENTED** with

- coarse-grained decomposition's,
- limited detail, and
- lower fidelity.

The correlation between the real world focus, the simulation focus, and the specific **REPRESENTATION** chosen is critical. For an identified simulation focus, **DATA** is created to complete the synthetic **REPRESENTATIONS** of these real world entities and actions for use in a simulation. Note that **REPRESENTATIONS** are plural here. For any specific entity or action, there is usually

- more than one **REPRESENTATION**

or within a particular **REPRESENTATION**

- more than one **MODEL** and/or
- more than one set of **DATA** elements

that provide an appropriate description of that entity or action depending upon the real world context and the simulation focus. That is, for any specific entity or action, there are families of distinct but related **REPRESENTATIONS**, **MODELS**, and/or **DATA**. Whether a verified and validated **REPRESENTATION** is **INFORMATION** or noise depends upon the end-use.

Minimum Requirement:

> **DATA** created, registered, maintained and released under the M&S Data Engineering Technical Framework shall be traceable to an appropriate **REPRESENTATION** of the implementation domain **ABSTRACTION** registered in a CMUS.

2.3 Primary Components

There are five primary components of the M&S Data Engineering Technical Framework:

- Common Semantics and Syntax
- Data Systems Architecture
- Data Processes
- Data Products
- M&S Functional Data Administration

2.3.1 Common Semantics and Syntax

A fundamental objective of data standards is to provide simulation developers and end-users with timely and cost-effective access to accurate **DATA** which are created, authenticated, and maintained by others. **DATA** recognition is the first requirement. No **DATA** set, however valuable, will be consider from inclusion in a composable solution if that data's suitability/appropriateness for the solution is not recognizable to the simulation developer or end-user. In many cases, the official language used by subject matter experts in distinct warfare or the well established nomenclature in a specific technologies is a barrier to this direct use and re-use of **DATA**. While correct and legitimate within its own domain, the official semantics and syntax in one warfare area or technical discipline often is in direct conflict with the formal language in another domain. Even at a basic vocabulary level, there are cases where identical words are used to mean very different things, and there are cases where different words are used to mean the same thing. To make effective use of Data Standards, simulation developers require **REPRESENTATIONS** and their associated **MODELS** and **DATA** that map domain specific descriptions to a common semantics and syntax.

SYNTAX

The symbols and structures which may be used in a **REPRESENTATION** and the ways that those symbols may be arranged within the allowed structures.

SEMANTICS

The content or meaning embodied in the symbols and symbol arrangements defined in a **SYNTAX**.

COMMON SEMANTICS AND SYNTAX

An implementation-independent logical specification of **REPRESENTATION** structure and content within a specified scope and context.

FORMAT

a set of semantic and syntactic conventions that define the physical implementation of **DATA**.

The central objective of **COMMON SEMANTICS AND SYNTAX** is **RESOURCE** recognition. For **DATA RESOURCES,** CSS is usually defined as an IDEF1X logical **DATA** model [10-12] with associated **DATA** element dictionary. Within the composable solutions strategy, CSS provides

- standard naming conventions in a common lexicon,
- entity-based and action-based data element dictionaries,
- common taxonomies within identified application clusters,
- layered architecture which separates implementation and problem domain semantics,
- integration with existing standards from other (non-M&S) functional areas, and
- capture, matching, and mapping procedures and utilities,

which enable simulation developers and end-users to readily recognize existing components as candidates for implementing their requirements.

The F/A-18 **REPRESENTATION** example cited in Section 2.2 is a special case of a more general observation [13] that **ABSTRACTION**

- in the form of a hierarchical chain of command and control is central to the planning and execution of military operations, and
- in the form of a hierarchical chain of components and networks is central to the processing characteristics and performance of military systems.

That is, real organizations and systems employ layered architectures to accommodate and implement the required hierarchies of abstraction. Therefore, CSS recognizes distinct but related families of **REPRESENTATIONS** in a layered architecture which explicitly mimics the real world usage of hierarchical **ABSTRACTION.**

Recall that the primary purpose of **COMMON SEMANTICS AND SYNTAX** is provide **DATA** recognition by making the **REPRESENTATION** explicit. Therefore the first step in developing CSS is to identify the key organizing principles (or primary dimensions) which describe the military activities of interest. As an example, consider the JWARS and JSIMS mission space. As illustrated in Figure 3, there are (at least) three primary organizing principles or dimensions:

- level of war,
- phase of campaign, and
- allegiance of forces

required to describe the JWARS and JSIMS mission space. While there certainly are more organizing principles within the JWARS/JSIMS domain (from example, analysis versus training), the number of primary dimension which can be accommodated is finite and usually less than seven [14]. Within any specific cell in Figure 3, CSS provides standards terms of reference, naming conventions, structures, and taxonomies based on the focus -- both real world and simulation related -- of the activities and entities in that cell. Between cells mapping and matching interfaces will be required -- either because the representations of the same real world entity/action are distinct or because the naming and nomenclature are distinct.

The organizing principles defined in Table 1 are of particular importance within the M&S Data Engineering Technical Framework. The Universal Joint Task List (UJTL) [15] defines military operations in terms of the four hierarchical layers (or levels of war) shown in the left most column of Table 1 as follows:

STRATEGIC LEVEL

The level at which national command authorities and combined operational commands determine the security objectives and warfare guidance with associated allocation of **RESOURCES**. With these objectives, guidance's, and **RESOURCES**, **STRATEGIC LEVEL** activities establish missions, national and multi-national objectives, sequence initiatives, define limits , and assess risks for the use of military and other instruments of national power. At the **STRATEGIC LEVEL**, the activities lead to the development of global and theater war plans and the provision of military forces and capabilities.

OPERATIONAL LEVEL

The level at which combined operational commands, joint and Service specific task forces plan, conduct, and sustain **STRATEGIC LEVEL** objectives within geo-spatial theaters of activity. These activities link the **STRATEGIC LEVEL** and the **TACTICAL LEVEL** by establishing objectives, sequencing events initiating actions, and applying **RESOURCES** at the appropriate **OPERATIONAL LEVEL**.

TACTICAL LEVEL

The level at which joint and Service specific task forces, individual military units, and multi-role platforms plan and execute the ordered arrangement and maneuver of combat elements in space and time relative to own and adversary forces to achieve combat objectives.

The **STRATEGIC LEVEL** is usually sub-divided into **STRATEGIC-NATIONAL** and **STRATEGIC-THEATER** levels as shown in the table. Within each UJTL level of war, the items to be **REPRESENTED** are organized according to:

TASK REPRESENTATION

The **REPRESENTATION** of actions to be executed and processes to be performed within a mission.

PHYSICAL REPRESENTATION

The **REPRESENTATION** of engineering, physics, chemistry, biology, or psychology principles to determine material characteristics and performance or to establish human cognitive and psychological factors.

WARFIGHTER REPRESENTATION

The **REPRESENTATION** of individual persons employing physical **RESOURCES** (platforms, systems, sensors, munitions, communications, etc.) to execute a task.

The DoD Instruction 5000.59 defines these types of simulations:

LIVE SIMULATION

Real **WARFIGHTERS** interacting with real systems in a real environment

VIRTUAL SIMULATION

Real **WARFIGHTERS** interacting with synthetic systems in a synthetic environment

CONSTRUCTIVE SIMULATION

Synthetic **WARFIGHTERS** interacting with synthetic systems in a synthetic environment

Cells in the same row of Table 1 share common actions and entities at the same level of warfare. Mapping and matching is required to substitute synthetic representation for real items when moving horizontally from real operations on the left to completely synthetic operations on the right. Cells in the same column share the same mixture of real and synthetic. Aggregation/de-aggregation interfaces are required to move vertically between levels of war.

Organization of **REPRESENTATIONS** according to

- UJTL level of warfare,
- degree of synthetic **REPRESENTATION**, and
- the relative focus among action, entity, or actor

are the foundation of **COMMON SEMANTICS AND SYNTAX** within the M&S Data Engineering Technical Framework. Therefore:

Minimum Requirement: **DATA** created, registered, maintained and released under the M&S Data Engineering Technical Framework shall be described using **COMMON SEMANTICS AND SYNTAX**, including but not limited to:

A taxonomy which identifies the key organizing principles and primary describing dimensions of the **REPRESENTATION** which the **DATA** completes. This taxonomy shall include but is not limited to the organizing principles defined in Table 1.

DATA element dictionary which complies with the DoD Data Dictionary System [4] structure and content specifications.

A **DATA** model which defines the relationships between the elements in the **DATA** dictionary within the taxonomy provided and which complies with the DoD Data Model [16] structure and content specifics.

Preferred Practice:

The required CSS **DATA** model and associated **DATA** elements should be constructed in accordance with DoD 5000.59-M-1 [17].

Technology Extension:

Employ the Data Analysis and Reconciliation Tool (DART) [18] to define entity-based **DATA** elements.

Employ the CMMS Verb Dictionary [19] to define action-based **DATA** elements

Employ the Comprehensive Utilities for Data Administration (CUDA) [20] procedure for reconciling and deconflicting **DATA** elements and **DATA** models.

2.3.2 Data Systems Architecture

RESOURCE realization as the central objective of **DATA** systems architecture within DE-TF. Systems architecture:

- defines the connection, location, and identification of key nodes, networks, and DBMS platforms and specifies the required system and component performance parameters, and
- is constructed to satisfy the operational architecture requirements in via products and standards defined in **DATA** Products.

The **DATA** systems architecture addresses system implementation requirements at two levels:

- the **DATA** development processes for creating, registering, maintaining, interchanging, and releasing of data prior to simulation execution, and
- the **DATA** employment processes for runtime selection and manipulation of data for employment or transmission during simulation execution.

The **DATA** development processes will be defined in Section 2.4.3 below. Discussion of the **DATA** employment processes is beyond the scope of DE-TF version 0.2.

DATA systems architecture describes how multiple **DATA** systems within a subject area link and interoperate. While external specifications are preferred, internal construction or operations of specific systems may be described where the internal details affect interoperability and reuse. In particular **DATA** systems architecture:

- describes the components and structure of the physical process which automate or enable **DATA** operations
- identifies system interfaces and defines the connectivity between systems,
- defines system constraints and bounds of system performance behavior,
- describes technology dependence is specific systems implementations, and
- shows systems interconnectivity from consumer through the repository to the producer (and authoritative data source) via the quality examiner, security officer, and requirements manager.

In DE-TF version 0.2, the data systems architecture specifies a minimal information systems infrastructure which is necessary (but not sufficient) for **DATA** realizations, including

- the Modeling and Simulation Resource Repository (MSRR) [1, 3] for consistent physical access and network connectivity,
- a families of **DATA** interfaces, and
- DISA Shared Data Environment (SHADE) [22] compatibility.

The MSRR is a collection of M&S registered **RESOURCES** and **RESOURCE** references, logically organized by information categories, and physically implemented using a distributed system of **RESOURCE** servers connected through the World Wide Web (WWW). The MSRR provides an additional layer of services above the WWW that includes registration of **RESOURCES**, users, and nodes; description and quality tagging of **RESOURCES**; security and releasability; and specialized search capabilities. MSRR provides a distributed repository for approved M&S **RESOURCES**. The primary objectives of the MSRR are to provide members of the M&S community with a facility to electronically:

- Register users, nodes, and **RESOURCES** with the MSRR Registrar.

- Store location and descriptive information about M&S **RESOURCES**.
- Protect sensitive but unclassified **DATA**.
- Store selected M&S **RESOURCES**.
- Search for **RESOURCES** via categories using search engines and database queries on the master registration database.
- Access authorized descriptive information about M&S **RESOURCES**.
- Navigate among the MSRR nodes and review **RESOURCES** on those nodes while retaining an MSRR identity.
- Access authorized M&S **RESOURCES** stored on the MSRR or on nodes external to the MSRR.
- Request M&S **RESOURCES** from **RESOURCE** providers.

Minimum Requirement:

> **DATA** systems implementations which support a **DATA** development processes shall be MSRR compliant.

The conversion and integration of data requires formal format standards and interfaces definitions. The **DATA** system architecture defines a hierarchical family of Data Interchange Format (DIF) definitions, interfaces, tools, and utilities including

- low level, file format or DBMS schema interface definitions in the form of Interface Description Language (IDL) [23], Structured Query Language (SQL) [24], and/or Backus Naur Form (BNF) [25],
- intermediate level, simulation developer Application Programming Interfaces (API's) in the form of Common Object Services Specifications (COSS) [26] and/or native programming language calls, and
- high level, simulation end-user Graphical User Interface (GUI) capability in the form of Common Object Facilities [27] and/or native windowing schema's.

Minimum Requirement:**:**

> **DATA** systems implementations which support a **DATA** development processes shall provide a low level format or schema interface definition using at least one of the following forms: OMG CORBA IDL, ANSI/ISO SQL, or BNF.

Preferred Practice: **DATA** systems implementations which support a **DATA** development process should:

> provide an intermediate, simulation developer API, either as an OMG COSS or as a set of native high-level programming language calls, and
>
> provide high level, simulation end-user Graphical User Interface (GUI) capability in the form of an OMG Common Object Facilities or a native windowing schema.

The DISA Shared Data Environment (SHADE) is an emerging DoD systems architecture standard for data. M&S Data Standard Architecture compatibility and interoperability with the SHADE beyond the scope of DE-TF version 0.2

2.3.3 Data Processes

DE-TF **DATA** process are decomposed into two primary activities -- those to develop required **DATA** prior to simulation execution and those to actually employ **DATA** during simulation execution:

DATA Development Processes

Descriptions of the tasks, operational elements, and information flows required for creating, registering, maintaining, interchanging, and releasing M&S **DATA** prior to simulation execution.

DATA Employment Processes

Descriptions of the tasks, operational elements, and information flows required for runtime selection and manipulation of M&S **DATA** for employment or transmission during simulation.

This section specifies the DE-TF **DATA** development processes. Discussion of the **DATA** employment processes is beyond the scope of version 0.2 of the M&S Data Engineering Technical Framework provided here.

REPRESENTATION implementation and **DATA** development are concurrent, spiral development activities [28, 29] which execute iteratively until the simulation life-cycle is complete. To meet these requirements, the **DATA** development processes defines two distinct (but compatible) views into the underlying **DATA** life-cycle:

- the closed-loop, repository-centric **DATA ENGINEERING PROCESS** (Figure 4)
- the developer-centric **DATA PRODUCTION SEQUENCE** (Figure 5) and

within the overall simulation development and employment life-cycle. The central objective of the **DATA** development processes are **RESOURCE** implementation repeatability. Within this objective:

- The **DATA ENGINEERING PROCESS** focuses on an iterative, spiral development life-cycle for enterprise use and re-use of **RESOURCES**.
- The **DATA PRODUCTION SEQUENCE** focuses on a once-through waterfall development process for delivering a specific version of a **RESOURCE** by a particular developer within the larger **DATA** Engineering Process spiral.

2.4.3.1 Operational Elements

There are five primary operational elements or functional roles performed by simulation developers, end-users, and problem domain experts shown as blocks within the **DATA ENGINEERING PROCESS** diagram depicted in Figure 4:

CONSUMER

The combination of **PERSON** and **ORGANIZATION** which executes the **ROLE** of **RESOURCE** employment. **PERSON**, **ORGANIZATION**, and **ROLE** are defined in [5, 29].

SPONSOR

The combination of a **PERSON**, **ORGANIZATION**, and **ROLE** which constitute the actor which has been assigned a.) the command responsibility for specific content, structure, quality, process, or ownership of a **RESOURCE** and/or b.) the management authority over the **RESOURCES** required to execute command responsibilities.

PRODUCER

The combination of **PERSON**, **ORGANIZATION**, and **ROLE** which constitute the actor who, because

of either mission or subject matter expertise, actually creates, manufactures, or constructs specific **RESOURCES**.

ADMINISTRATOR

The combination of **PERSON** and **ORGANIZATION** which executes the **ROLE** of **RESOURCE** repository management.

EXAMINER

The combination of a **PERSON**, **ORGANIZATION**, and **ROLE** which constitute the actor that actually inspects, tests, and evaluates specific **REPRESENTATION** content, structure, or process for the purpose of verification, validation, and certification or accreditation.

2.4.3.2 Information Exchange Requirements

There are seven primary information exchange requirements (or interactions) between the five operational elements (or functional roles) shown as arrows within the **DATA** Engineering Process diagram shown in Figure 4:

SPECIFY

The explicit description of requirements for a **RESOURCE. SPECIFY** provides the black-box definition of external characteristics, performance, capabilities, and interfaces required of a **RESOURCE** in the form of CMMS and CMUS **REPRESENTATIONS** and, for **DATA RESOURCES DATA** element dictionaries and (IDEF1X) **DATA** models defining the logical content and physical constraints. The **CONSUMER** has the lead **ROLE** to propose and deliver **RESOURCE SPECIFICATIONS**. The **SPONSOR** has the response **ROLE** to identify, review, and concur with **RESOURCE SPECIFICATIONS**.

ENDORSE

The formal delegation of **SPONSOR** authority to implement an **APPROVED RESOURCE** by expending **RESOURCES ALLOCATED** for that purpose. The **SPONSOR** has the lead **ROLE** to propose and deliver an **ENDORSEMENT**. The **PRODUCER** has the response **ROLE** to identify, review, and concur with an **ENDORSEMENT**.

REGISTER

The formal delivery of a **RESOURCE** for actual inclusion in a repository, especially MSRR, including source, format, and content checking with deficiency correction as appropriate. The **PRODUCER** has the lead **ROLE** to propose and deliver a **REGISTRATION** subject to **SPONSOR APPROVAL**. The **ADMINISTRATOR** has the response **ROLE** to identify, review, and concur with a **REGISTRATION** subject to **SPONSOR ALLOCATION**.

RELEASE

The formal permission to delivery a **RESOURCE** for **CONSUMER** activities, especially via MSRR, including the provision of security services, access control, user identification for use and examination of the **RESOURCE.** The **ADMINISTRATOR** has the lead **ROLE** to enforce release policy subject to sponsor approval and the response **ROLE** to deliver **RELEASED RESOURCES** subject to **SPONSOR ALLOCATION**. The **CONSUMER** has the lead **ROLE** to propose and justify **RESOURCE RELEASE** and the response **ROLE** to receive **RELEASED RESOURCES**.

REQUEST

The identification of the need for a formal **RESOURCE EXAMINATION.** The **CONSUMER** has the lead **ROLE** to identify the **RESOURCE** and to propose the **EXAMINATION**. The **EXAMINER** has the response **ROLE** to review and concur with the proposed **RESOURCE EXAMINATION** subject to **SPONSOR AUTHORIZATION**.

AUTHORIZE

The combination of **APPROVAL AND ALLOCATION** which constitute formal sanction of the requirement to **EXAMINE** a resource, of the designation of a **RESOURCE** as **AUTHORITATIVE**, or of the permission to **RELEASE** a **RESOURCE. .** The **SPONSOR** has the lead **ROLE** provide **AUTHORIZATION**. The **CONSUMER**, **PRODUCER**, **ADMINISTRATOR**, and **EXAMINER** have the response **ROLE** to review and concur with proposed **AUTHORIZATIONS**.

SUBMIT

The formal delivery of a resource for **EXAMINATION.** The **PRODUCER** has the lead **ROLE** to assemble, format, package, and deliver the **RESOURCE** and supporting meta-**DATA** for use by the **EXAMINER**. The **EXAMINER** and **CONSUMER** has the response **ROLE** to identify, review, and concur with the **RESOURCE SUBMISSION** subject to **SPONSOR AUTHORIZATION**.

2.4.3.3 Activities

Within the five primary operational elements or functional **ROLES** performed by simulation developers, end-users, and problem domain experts, there are a number of activities conducted primarily or exclusively by that functional **ROLE**. These activities are shown as a list of actions within the operational element blocks within the **DATA** Engineering Process diagram shown in Figure 4:

The **CONSUMER ROLE** executes these four **DATA** Engineering Process activities:

LOCATE

The use of on-line browsing tools, automated searches, and retrieval queries to identify **RESOURCES** of interest. **COMMON SEMANTICS AND SYNTAX** is applied to construct searches and to recognize **RESOURCES**.

ACCESS

The use of **RESOURCE** retrieval services to obtain located **RESOURCES**. For **DATA RESOURCES, DATA INTERCHANGE FORMATS** are employed via application programming interfaces and/or graphical user interface (GUI) services to gather, **FORMAT**, package, and deliver **DATA** to the **CONSUMER.**

EVALUATE

CONSUMER actions to determine that a particular **RESOURCE** does or does not satisfies specific **CONSUMER** requirements.

EMPLOY

CONSUMER usage of a particular **RESOURCE** to satisfy specific end-use requirements.

The **SPONSOR ROLE** executes these two **DATA** Engineering Process activities:

APPROVE

The command decision and official sanction with respect to a **RESOURCE** that a requirement is justified, a **REGISTER** or **RELEASE** is appropriate, an **EXAMINATION** is satisfactory, or a **DATA SOURCE** is **AUTHORITATIVE.**

ALLOCATE

The programmatic authority and official sanction to expend **RESOURCES** to fulfill a requirement, to perform a **REGISTER** or conduct a **RELEASE**, or to conduct an **EXAMINATION.**

The **PRODUCER ROLE** executes these four **DATA** engineering process activities:

DESIGN

The deliberate purposive planning by which the nature and arrangement of elements which constitute a **RESOURCE** are described and a scheme for implementing these elements is devised. **DESIGN** provides the clear-box definition of the internal elements of a **RESOURCE**.

CREATE

The actual construction of a **RESOURCE**.

CONVERT

Transformation of a **REGISTERED RESOURCE** from its native form into **DATA** in a standard form with **COMMON SEMANTIC AND SYNTACTIC** elements for archive and interchange.

INTEGRATE

The act of combining, normalizing, mapping, matching, indexing, and in general migrating **REGISTERED DATA** in standard form to a higher level of syntatic maturity and semantic enforcement within a common repository.

The **ADMINISTRATOR ROLE** executes these four **DATA** engineering process activities:

CATALOG

The provision of a complete enumeration of **REGISTERED RESOUCES** arranged systematically within an appropriate taxomony which provides meta-**DATA** and descriptive details to support **CONSUMER LOCATE** and **ADMINISTRATOR STORE, CONFIGURE,** and **PURGE** activities.

STORE

The provision of resource persistence and recovery. For **DATA RESOURCES,** the provision of persistent file server and DBMS **RESOURCES**.

CONFIGURE

The provision of **RESOURCE** configuration management, version control, and change traceability.

PURGE

The removal and retirement of (previously) persistence **RESOURCES**.

2.3.3.4 Data Production Sequence

While the **DATA ENGINEERING PROCESS** provides a view of the overall use and reuse of **DATA** via a common (likely distributed) repository, the **DATA PRODUCTION SEQUENCE** (Figure 5) focuses on the development of a specific set of **DATA** instances:

- by a **PRODUCER,**
- to complete an explicit **REPRESENTATION,**
- to meet an **ENDORSED** set of requirements,
- as specified by a **CONSUMER**.

The **DATA PRODUCTION SEQUENCE** is a refinement and elucidation of the **DESIGN** and **CREATE** activities. Within this sequence, the **PRODUCER** has the lead **ROLE** to propose and conduct the activities and initiate the information exchanges required to ultimately construct the required **DATA.** The **CONSUMER, ADMINISTRATOR, EXAMINER** and **SPONSOR** have the response **ROLE** to identify and provide the **AUTHORIZED** input **RESOURCES** for the **CREATE**-related activities and to review and concur with **DESIGN**-related activities.

This sequence is composed of four primary activities conducted by the **PRODUCER** operational element, with appropriate assistance from the other operational elements. These activities are shown as a sequence of boxes within the **DATA** Engineering Process diagram shown in Figure 5:

DEVELOP FOCUSED CONTEXT

SPECIFY concrete operational conditions using CMMS **REPRESENTATIONS**, establish end-user priorities and constraints using CMUS **REPRESENTATIONS**, and establish output **RESOURCE** requirements using **ENDORSED SPECIFICATIONS**.

GATHER INFORMATION

Establish the preliminary design by conducting coordinated **RESOURCE** repository searches and site-visits to subject matter experts to **LOCATE**, **EVALUATE**, and ultimately obtain **RELEASE** of required input **RESOURCES** within the **FOCUSED CONTEXT**.

FORMALIZE INPUT RESOURCES

Complete the detailed **DESIGN** the required resource by organizing the input **RESOURCES**, using **COMMON SEMANTICS AND SYNTAX** and **DATA INTERCHANGE FORMATS**, where appropriate, into standard forms for **PRODUCTION** use.

CONSTRUCT RESOURCE

EMPLOY the **FORMALIZED INPUT RESOURCES** to **PRODUCE** the required output **RESOURCES**.

The arrows between the activity blocks in Figure 5 represent information exchange requirements, likely via MSRR, as define in Section 2.4.3.2 above.

Minimum Requirement:

DATA CREATED, **REGISTERED**, maintained and **RELEASED** under the M&S Data Engineering Technical Framework shall be **PRODUCED** in accordance with the **DATA PRODUCTION SEQUENCE**.

DATA CREATED and **EMPLOYED** under the M&S Data Engineering Technical Framework shall be **SPONSORED, PRODUCED**, **EXAMINED**, **ADMINISTERED**, and **CONSUMED** in accordance with the **DATA ENGINEERING PROCESS.**

2.4.4 Data Products Technical Architecture

The central **DATA** products objective is to enable the composable solutions strategy by defining reusable, shrink-wrapped **RESOURCES**. For **DATA RESOURCES**, DE-TF defines five key **DATA** products

- authoritative data sources
- authorized data consumers
- data interchange formats
- data quality products and procedures
- data security products and procedures

2.3.4.1 Authoritative Data Sources

This section describes the **REPRESENTATION** requirements which ensure that the accuracy and authenticity of any particular **DATA** is specified in sufficient detail for a simulation developer or end-user

to recognize the suitability of that **DATA** for that simulation developer's or end-user's specific requirements.

PRODUCTION PEDIGREE

The comprehensive audit trail which describes the specific methods and procedures actually employed by the **PRODUCER** to create, derive, and construct a particular **DATA** instance for specified end-use. This **PEDIGREE** provides **DATA SOURCE** traceability for constituent **DATA** instances which were incorporated into or employed to produce the particular **DATA** instance in question.

DATA SOURCE (DS)

The combination of **SPONSOR**, **PRODUCER**, **DATA**, and **PRODUCTION PEDIGREE** which provide a **DATA** instance. The **PRODUCER** creates the actual **DATA** instance by direction of the **SPONSOR** and records these activities in the **PEDIGREE**. This definition of **DATA SOURCE** is a compatible extension of the definitions in [3-4].

VV&C PEDIGREE

The comprehensive audit trail which records the formal verification, validation, and accreditation activities actually performed on a particular **DATA SOURCE** by the **EXAMINER**. This **PEDIGREE** also provides traceability for input **DATA** instances or **MODELS** which a.) were employed to produce the actual **DATA** instances provided in the **DATA SOURCE** in question but which b.) were not delivered along with these actual **DATA** instances being **EXAMINED**.

AUTHORITATIVE DATA SOURCE (ADS)

The combination of **SPONSOR**, **EXAMINER**, **DATA SOURCE**, and **VV&C PEDIGREE** which provide one or more **DATA** instances have verified, validated, certified/accredited in accordance with appropriate DoD or Service **VV&C** procedure. The **EXAMINER** analyzes that actual **DATA** instance provide by the **DATA SOURCE** under direction of the **SPONSOR** and records these activities in the **VV&C PEDIGREE**. This definition of **AUTHORITATIVE DATA SOURCE(ADS)** is a compatible extension of the definitions in [3-4].

Minimum Requirement:

All **DATA** shall be **REGISTERED** by an **AUTHORITATIVE DATA SOURCE** which have been **APPROVED** by an appropriate Joint, Service, or Agency **SPONSOR**.

For example, in the military operation mission space, the actual warfighter in hostile, live-fire combat operations is the original **DATA SOURCE**. However, simulations based on such a **DATA SOURCE** are of minimal value in the absence of verification, validation, and eventually accreditation. Doctrine is a disciplined attempt to learn for these warfighter experiences. Just so, the requirement that all **DATA** be **REGISTERED** by an **AUTHORITATIVE DATA SOURCE** is an attempt to introduce that same discipline into simulations. This **ADS** framework provides the rigorous **DATA SOURCE** traceability and configuration management which is required to support **VV&C** by competent authority.

Preferred Practice:

To support concurrent work-in-progress by **DATA SOURCE, VV&C EXAMINER,** and simulation developers, **DATA** from a **SPONSOR APPROVED DATA SOURCE** may be **REGISTERED, CONVERTED,** and **INTEGRATED** in parallel with **EXAMINER** activities to provide the required **VV&C** for **AUTHORITATIVE DATA SOURCE** approval.

2.3.4.1 Authorized Data Consumers

This section describes the requirements which control the **RELEASABILITY** of any particular **DATA** to a specific simulation developer.

CLEARANCE

The **AUTHORIZATION** that a specific **CONSUMER** is legally eligible to be entrusted with classified, proprietary, or otherwise sensitive **DATA** instance.

ACCESS

The **AUTHORIZATION** that a specific combination of a **CONSUMER** with a particular **CLEARANCE** under the authority of an identified **SPONSOR** has an appropriate need-to-know for a specific classified, proprietary, or otherwise sensitive **DATA** instance.

SECURITY PEDIGREE

The comprehensive audit trail which records the specific methods and procedures actually employed by the **CONSUMER** under authority of the **SPONSOR** to ensure that any specific **DATA** instance has been properly protected

DATA CONSUMER (DC)

The combination of **SPONSOR**, **CONSUMER**, **CLEARANCE**, **ACCESS**, and **SECURITY PEDIGREE** which requests permission to **LOCATE**, **EXTRACT**, or **EVALUATE** a specific **DATA** instance. The **CONSUMER** requests and eventually receives the actual **DATA** instance by direction of the **SPONSOR** and records these activities in the **SECURITY PEDIGREE**.

RELEASE PEDIGREE

he comprehensive audit trail which records the specific methods and procedures actually employed by the **ADMINISTRATOR** under authority of the **AUTHORITATIVE DATA SOURCE** (**ADS**) to **RELEASE** any specific **DATA** instance to a **DATA CONSUMER**.

AUTHORIZED DATA CONSUMER

The combination of **DATA CONSUMER**, **AUTHORITATIVE DATA SOURCE** and **RELEASE PEDIGREE** certifies the **RELEASE** of one or more **DATA** instances from the **AUTHORITATIVE DATA SOURCE** to the **DATA CONSUMER**. The **ADMINISTRATOR** records these activities in the **RELEASE PEDIGREE**. This definition of **AUTHORIZED DATA CONSUMER** (**ADC**) is a compatible extension of the definitions in [3-4].

Minimum Requirement:

> Each **CONSUMER** shall be an **AUTHORIZED DATA CONSUMER. DATA** shall not be **RELEASED** to any **CONSUMER** who is not an **AUTHORIZED DATA CONSUMER.**

2.3.4.3 Data Interchange Formats

[TBD]

2.3.4.4 Data Quality Products and Procedures

[TBD]

2.3.4.5 Data Security Products and Procedures

[TBD]

2.3.5 Functional Data Administration

[TBD]

3. Detailed Definition of M&S DE-TF Products and Processes

[TBD]

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5. Figures

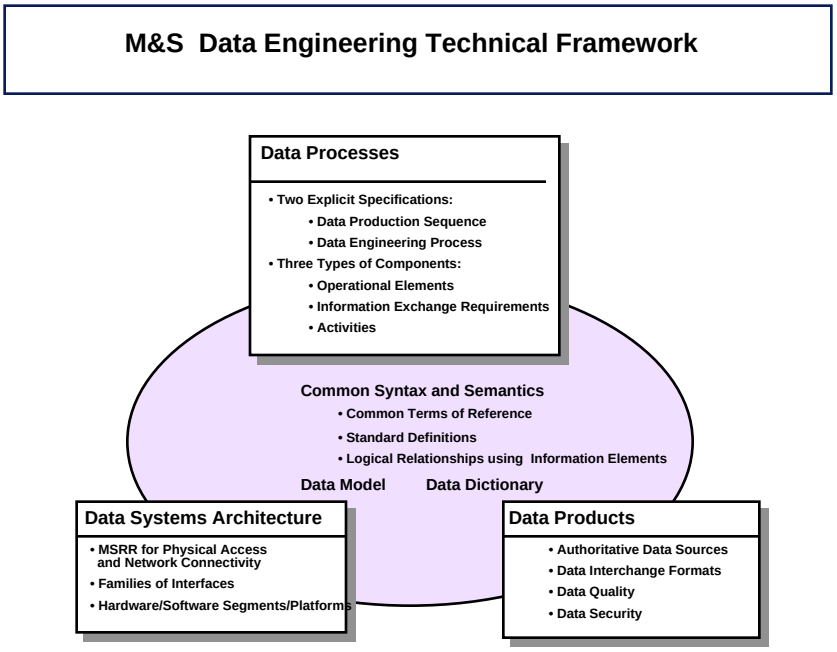

Figure 1

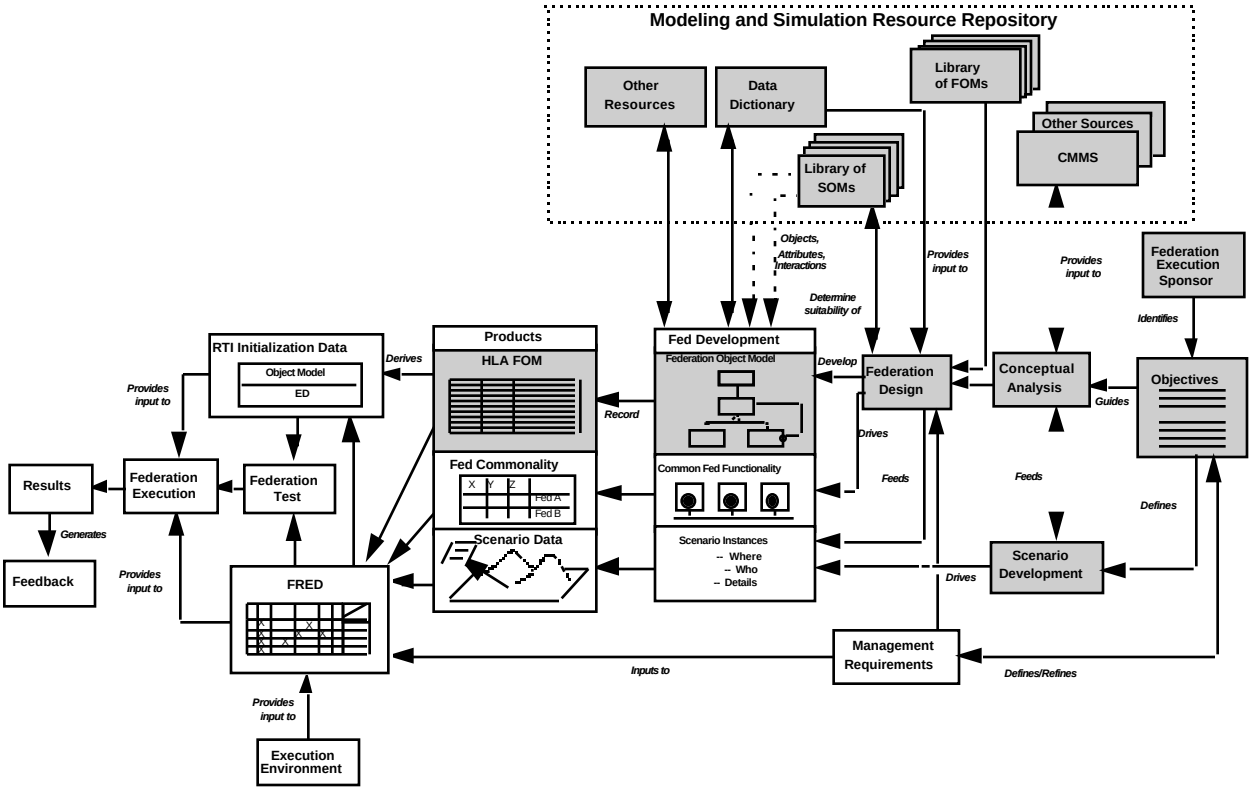

Figure 2-1. Federation Development and Execution Process Model

JWARS/JSIMS Mission Space

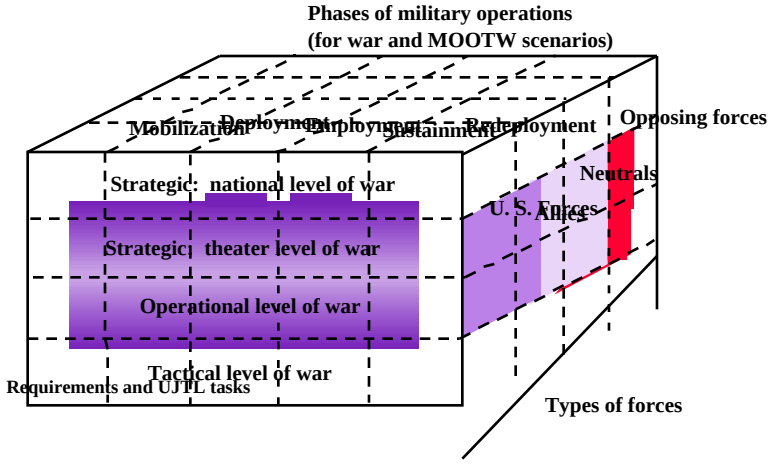

Figure 3

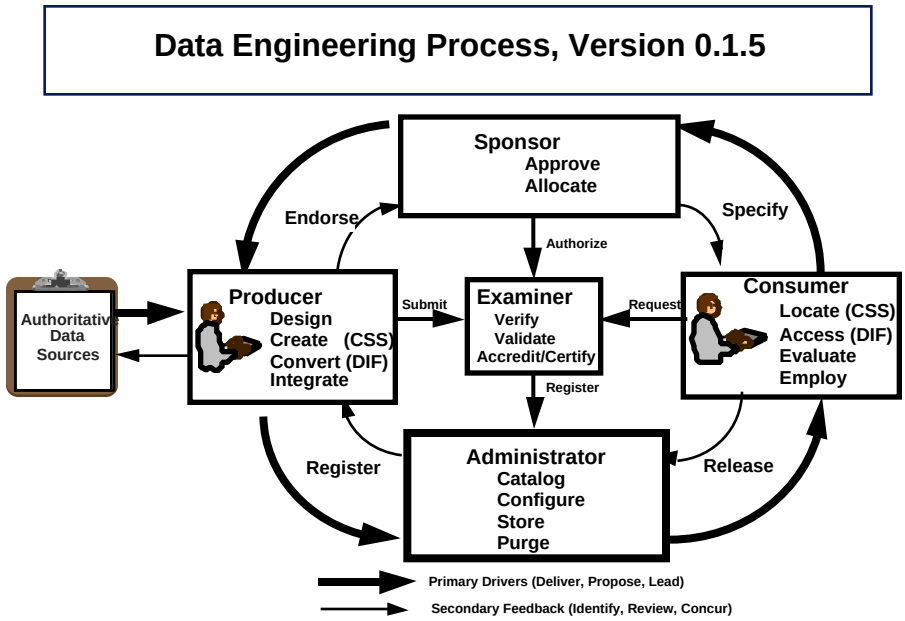

Figure 4

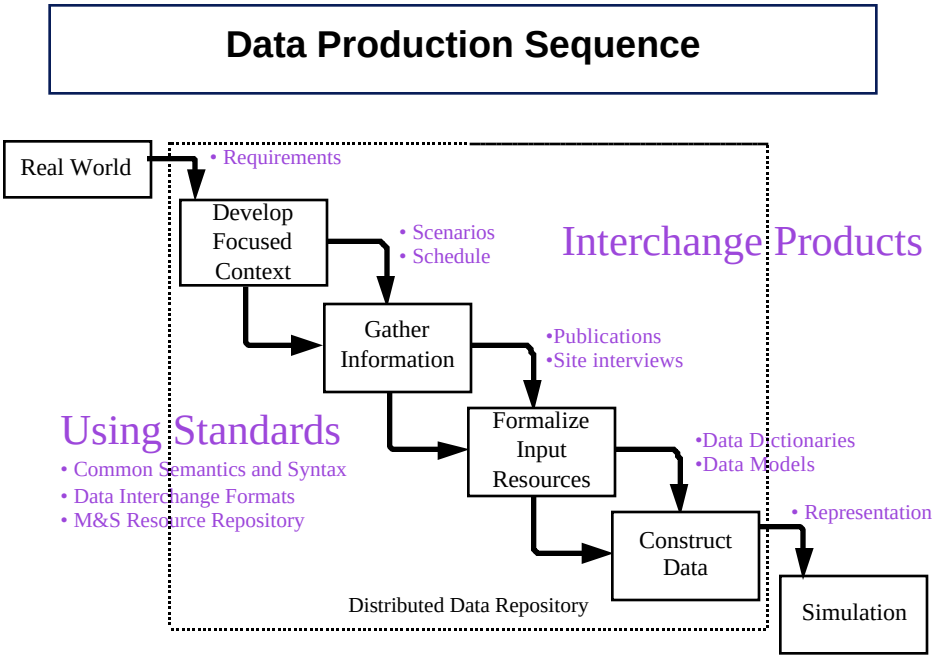

Figure 5

6. Tables

Table 1

UJTL LEVEL OF WAR	LIVE SIMULATION	VIRTUAL SIMULATION	CONSTRUCTIVE SIMULATION
STRATEGIC NATIONAL			
TASK	synthetic	synthetic	synthetic
PHYSICAL	real	synthetic	synthetic
WARFIGHTER	real	real	synthetic
STRATEGIC THEATER			
TASK	synthetic	synthetic	synthetic
PHYSICAL	real	synthetic	synthetic
WARFIGHTER	real	real	synthetic
OPERATIONAL			
TASK	synthetic	synthetic	synthetic
PHYSICAL	real	synthetic	synthetic
WARFIGHTER	real	real	synthetic
TACTICAL			
TASK	synthetic	synthetic	synthetic
PHYSICAL	real	synthetic	synthetic
WARFIGHTER	real	real	synthetic

7. Specifications Compendium

7.1. Minimum Requirements:

1 **DATA** created, registered, maintained and released under the M&S Data Engineering Technical Framework shall be traceable to an appropriate **REPRESENTATION** of the corresponding problem domain **ABSTRACTION** registered in CMMS.

2 **DATA** created, registered, maintained and released under the M&S Data Engineering Technical Framework shall be traceable to an appropriate **REPRESENTATION** of the implementation domain **ABSTRACTION** registered in a CMUS.

3 **DATA** created, registered, maintained and released under the M&S Data Engineering Technical Framework shall be described using **COMMON SEMANTICS AND SYNTAX**, including but not limited to:

3.1 A taxonomy which identifies the key organizing principles and primary describing dimensions of the **REPRESENTATION** which the **DATA** completes. This taxonomy shall include but is not limited to the organizing principles defined in Table 2.

3.2 **DATA** element dictionary which complies with the DoD Data Dictionary System [5] structure and content specifications.

3.3 A **DATA** model which defines the relationships between the elements in the **DATA** dictionary within the taxonomy provided and which complies with the DoD Data Model [17] structure and content specifics.

4 **DATA** systems implementations which support a **DATA** development process shall be MSRR compliant.

5 **DATA** systems implementations which support a **DATA** development process shall provide a low level format or schema interface definition using at least one of the following forms: OMG CORBA IDL, ANSI/ISO SQL, or BNF.

6 **DATA CREATED**, **REGISTERED**, maintained and **RELEASED** under the M&S Data Engineering Technical Framework shall be produced in accordance with the **DATA PRODUCTION SEQUENCE.**

7 **DATA CREATED** and **EMPLOYED** under the M&S Data Engineering Technical Framework shall be **SPONSORED, PRODUCED**, **EXAMINED**, **ADMINISTERED**, and **CONSUMED** in accordance with the **DATA ENGINEERING PROCESS.**

8 All **DATA** shall be **REGISTERED** by an **AUTHORITATIVE DATA SOURCE** which have been **APPROVED** by an appropriate Joint, Service, or Agency **SPONSOR**..

9 Each **CONSUMER** shall be an **AUTHORIZED DATA CONSUMER**. **DATA** shall not be **RELEASED** to any **CONSUMER** who is not an **AUTHORIZED DATA CONSUMER.**

7.2 Preferred Practices

1 The required CSS **DATA** model and associated **DATA** elements should be constructed in accordance with DoD 5000.59-M-1 [18].

2 **DATA** systems architecture implementations which support a **DATA** development process should:

2.1 provide an intermediate, simulation developer API, either as an OMG COSS or as a set of native high-level programming language calls, and

2.2 provide high level, simulation end-user Graphical User Interface (GUI) capability in the form of an OMG Common Object Facilities or a native windowing schema.

3 To support concurrent work-in-progress by **DATA SOURCE**, **VV&C EXAMINER**, and simulation developers, **DATA** from a **SPONSOR APPROVED DATA SOURCE** may be **REGISTERED**, **CONVERTED**, and **INTEGRATED** in parallel with **EXAMINER** activities to provide the required **VV&C** for **AUTHORITATIVE DATA SOURCE** approval.

7.3 Technology Extensions

1 Employ the Data Analysis and Reconciliation Tool (DART) [19] to define entity-based **DATA** elements.

2 Employ the CMMS Verb Dictionary [20] to define action-based **DATA** elements

3 Employ the Comprehensive Utilities for Data Administration (CUDA) [21] procedure for reconciling and deconflicting data elements and data models.

Enclosures [TBD]

Annexes [TBD]